Charge Transfer of Multiply Charged C, N and O Ions in Collisions with H_2 at Low Energies below 1 keV/u

Y. Inoue, K. Ishii[1], H. Ogawa[1], A. Itoh[2] and N. Sakamoto[1]

Graduate school of Humanities and Science, Nara Women's University, Nara, 630-8506, JAPAN
[1]Dept. of Physics, Nara Women's University, Nara, 630-8506, JAPAN
[2]Dept. of Nuclear Engineering, Kyoto University, Kyoto, 606-8501, JAPAN

ABSTRACT

We have measured energy gain spectra for single-electron capture in collisions of He-like C, N and O ions with H_2 and N_2 at 50 and 1000 eV/u. Energy gain spectra were examined with energy gain functions calculated from a classical over barrier model, and we obtained fairly good agreement between experimental and calculated results. We find that single electron capture occurs predominantly for C^{4+}+ H_2, O^{6+}+ H_2 and N^{5+}+ N_2 while for N^{5+}+ H_2 double electron capture followed by transfer ionization is the dominant process in the formation of N^{3+} ions.

INTRODUCTION

Single and double electron capture collisions between a multiply charged ion A^{q+} and H_2 are written as

$$
\begin{aligned}
A^{q+} + H_2 &\rightarrow A^{(q-1)+}(nl) + H_2^{+} + \Delta E_1 && \cdots \sigma_{(nl)} \\
&\rightarrow A^{(q-2)+}(nl\ n'l') + (H_2)^{2+} + \Delta E_2 && \cdots \sigma_{(nl\ n'l')} \\
&\rightarrow A^{(q-1)+} + e^{-} && \cdots \sigma_{TI} \\
&\rightarrow A^{(q-2)+} + h\nu && \cdots \sigma_{DC}
\end{aligned}
$$

$$
\sigma_{SC} = \sum \sigma_{(nl\ n'l')} + \sigma_{TI} .
$$

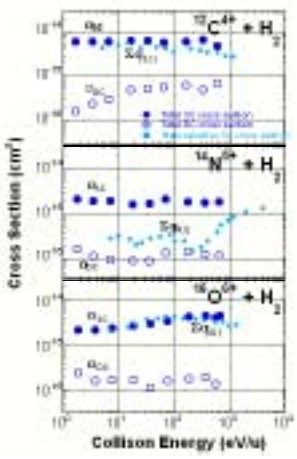

Figure 1 : Absolute total electron capture cross sections and state selective electron capture cross sections of He-like C, N and O ions in collisions with H_2 molecule below 1 keV/u [1,2].

below 500 eV/u

- C^{4+} + H_2 : $\sigma_{sc} = \Sigma\sigma_{(3,l)}$
- N^{5+} + H_2 : $\sigma_{sc} \neq \Sigma\sigma_{(4,l)}$
- O^{6+} + H_2 : $\sigma_{sc} = \Sigma\sigma_{(4,l)}$

N^{4+} ions are produced predominantly via a transfer ionization (TI) process below energies 500 eV/u.

In this work, in order to understand these characteristics for above features, we have measured energy gain spectra for He-like C, N and O ions with H_2 at 50 eV/u. Results are examined within the framework of the classical over barrier (COB) model[3].

EXPERIMENTAL SETUP

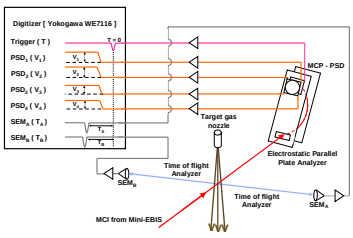

Figure 2 : Schematic diagram of experimental setup.

RESULTS and DISCUSSION

We calculated energy window functions in the COB frames by Niehaus. (Assuming Gaussian distributions.)

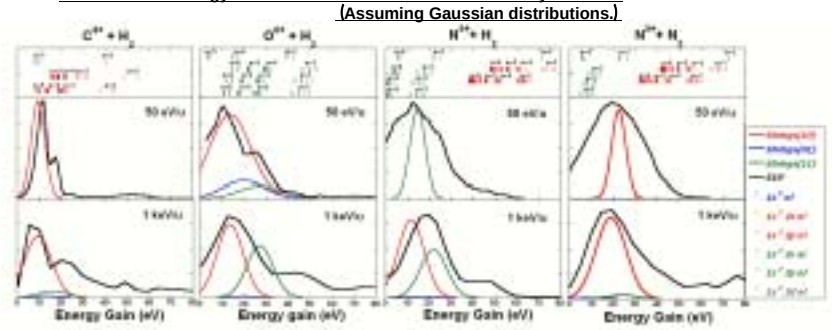

Figure 3 : Measured energy gain spectra of C^{4+}, N^{5+} and O^{6+} in collisions with H_2, N_2 at 50 and 1000 eV/u (Black lines). Calculated energy gain function (Red, blue and green lines) and energy states are also shown[3,4].

- Single electron capture is the predominant process for C^{4+}+ H_2, O^{6+}+ H_2 and N^{5+}+ N_2 while double electron capture into auto-ionizing states is predominant in the collision system of N^{5+}+ H_2.
  => N^{5+} ions independent target molecular.

SUMMARY

We have

- measured energy gain spectra for single-electron capture in collisions of He-like C, N and O ions with H_2 and N_2 at 50 and 1000 eV/u.
- reproduced measured results by estimated energy gain functions based on COB model.
- confirmed that the predominant channels for C^{4+}+ H_2, O^{6+}+ H_2 and N^{5+}+ N_2 were single electron capture but that for N $^{5+}$+ H_2 was TI process.

FUTURE PLAN

To understand more precisely for this work,

- measurements of energy gain spectra with high resolution.
- coincidence measurements with fragment ions from target molecules.

PROGRESS REPORT

Recently, we have studied that collisions between highly charged ion and molecular target at collision energies below 500 eV/u to understand dynamics of molecular fragmentation at low energies.

- We have measured TOF of fragment ion from target molecules.
  => Figure 4

Molecular ion peaks (⬇ and ⬇) move to the left-hand side with decreasing collision energy. This phenomenon is called the "Peak Shifting ".
The "Peak Shifting" can be explained by the transverse recoil momentum; eq.(1). The collision energy dependence of the scattering angle is eq.(2). Therefore, we obtain eq.(3). In other words, the transverse recoil momentum decrease with increasing collision energy.

$$
\begin{aligned}
P_{\perp} &\cong \sqrt{E_{CM}}\,\Theta_{CM} && \cdots(1) \\
&\downarrow \quad E_{CM}\,\Theta_{CM} \cong \text{Const.} && \cdots(2) \\
P_{\perp} &\propto E_{CM}^{-1/2} && \cdots(3)
\end{aligned}
$$

$P_{\perp}$: Transverse recoil momentum
E_{CM} : Energy of CM - system
Θ_{CM} : Angular of CM - system

- We are planning to measure coincidence TOF of fragment ion pair from target molecules with charge transferred HCl.

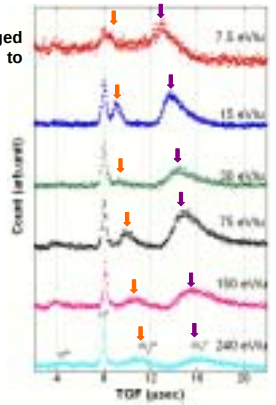

Figure 4 : Measured TOF spectra of Ar^{6+} in collisions with N_2 at 7.5 - 240 eV/u. There are 4 peaks, which correspond to N^+, N^{2+}, $(N_2)^+$ and $(N_2)^{2+}$.

REFERENCES

[1] G. Lubinski, Z. Juhasz, R, Morgenstern and R. Hoekstra, J. Phys. B 33 (2000) 5275.
[2] K. Ishii, A. Itoh and K. Okuno, not published.
[3] A. Niehaus, J. Phys. B 19 (1986) 2925-2937.
[4] WWW homepage of the NIST Atomic Spectra Database (*http://physics.nist.gov/*).
[5] K. Ishii, Y. Inoue, H. Ogawa, A. Itoh and N. Sakamoto, J. Phys: Conf. Ser. 58 (2007) 279-282